An Introduction to Electronics Systems Packaging

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Module No. # 01

Lecture No. # 04

Packaging Aspects of Handheld Products

Case Studies in Applications

Welcome back to this video course on electronic systems packaging. We are now looking at the introductory chapter on the overview of electronic systems packaging. We will continue to do so. However, before that, I hope you have gone through the previous lectures and got a firm footing about the basics of certain definitions of electronic systems packaging because I think this is very important and necessary to have a feel of what, where we are heading towards, what topics we are going to cover, and so on.

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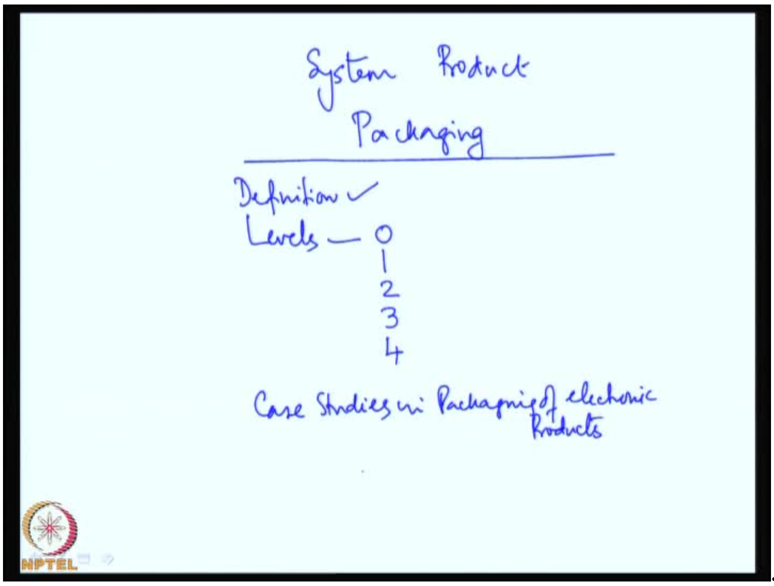

I will briefly write some terms here that we have discussed. For example, I am sure that you are now confident of using the term System. You can describe what a System is, you can describe what a Product is, and you can talk Packaging with respect to System or a Product.

In the last class, we had defined what packaging is. If you remember, I have given about two or three definitions for electronic systems packaging or electronics packaging. Then, we have seen the levels of packaging. If you recollect, we are talking about level 0, level 1, 2, 3, and 4. Level 0 to 4 comprises various activities, which you are now going to review again today, if you are not really comfortable. Then, today, we are going to focus on some case studies in packaging of electronic products in various sectors. As an engineer, this case study will give you an overview of what considerations you need to look at when you are designing a product and what is the requirement of a consumer or an end user.

During the course of these slides, again if you have any questions, please email so that more information can be given depending upon your query. At the end of this first chapter, I am planning to give a tutorial, some question answers sessions so that you will be very comfortable with what kind of queries; as an academic program, if you are taking this course elsewhere, you can expect what kind of situations you need to be aware of through these tutorials.

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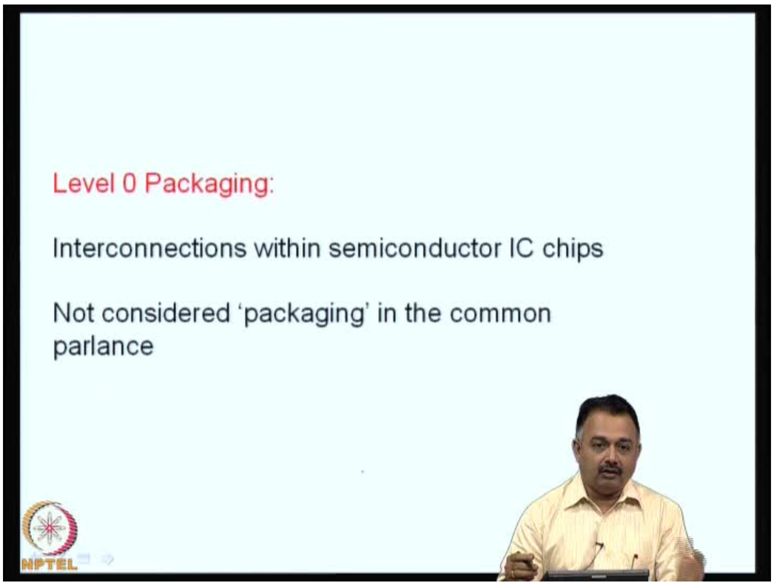

We will start with the first slide. If you look at this slide, here I have depicted the Level 0 Packaging activity as described earlier from VLSI CAD activity. We are now interested in establishing interconnections between semiconductor IC devices or chips. There will be a lot of gates or transistors with which you have to establish connections. Typically copper interconnections because copper as you know is a very good conductor. So, we use CAD activity to establish or design interconnections within semiconductor IC devices. However, actually this particular activity is not considered a packaging activity in the common parlance because it comes under semiconductor packaging. So, the following activities will actually cover systems packaging.

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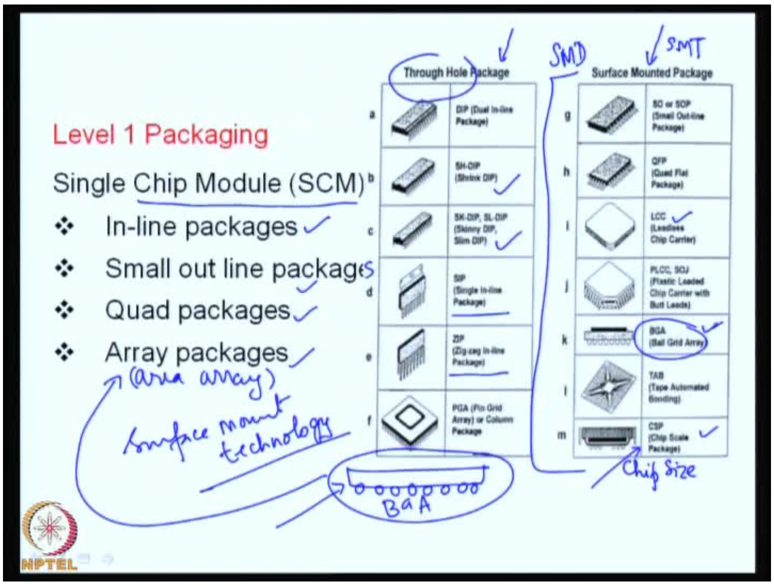

Level 1 Packaging will involve the formation of packages from these dies. So, you have what is known as a Single Chip Module, SCM – Single Chip Module or Single Chip Packages. In that the classifications are: In-line packages, Small out-line packages, Quad packages, and Array packages. There is also another term called Area Array packages, which is the same as Array packages. We will carefully see what each one means. I would like to exhibit some more samples today or probably the same samples that I showed in the previous hour so that you can refresh and really understand what I am talking about. If you look at the slide, there are two basic classifications: one is a Through Hole Package and the other is a Surface Mount Package.

We are going to study in detail what exactly is meant by Through Hole Package and Surface Mount Package. However, upfront as the name indicates, Through Hole Package means a device, which consists of pins.

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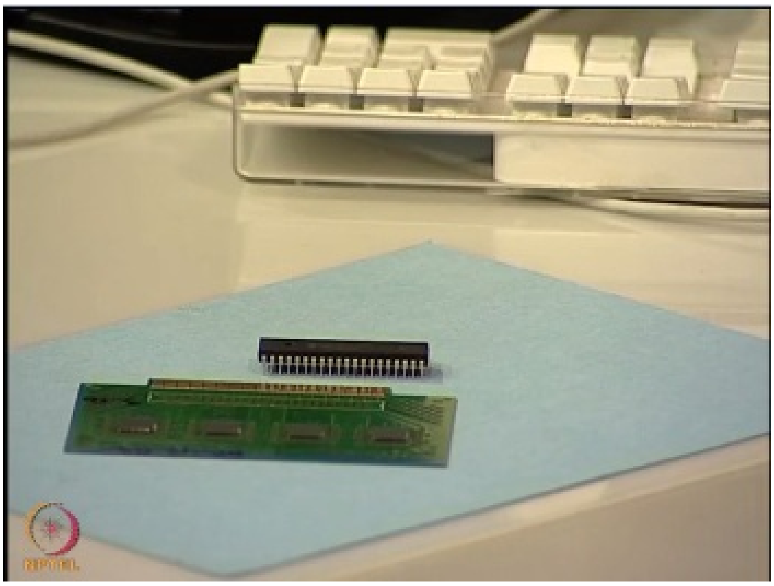

As you can see here, the device consists of pins. The pins have to be inserted into a Printed Wiring Board of this type, which means the holes are necessary to be fabricated in this Printed Wiring Board and this goes inside the through hole of the board. So, those packages are known as Through Hole Packages; very simple, in that you have Dual In-line Package. What you are seeing here exactly is a Dual In-line Package because you have two rows of pins. So, it is a Dual In-line Package. Then, you have packages, which are shrink. You see – there is a definite height for these pins. In shrink packages, this height will be reduced. Those are called Shrink Dual In-line Packages. Then comes Skinny or Slim Dual In-line Packages. These are also available in the market today.

Then comes a new category called Single In-line Packages. Instead of having Dual In-line Package, some packages will exhibit only one row of pins, which will go on to the board. So, those are known as Single In-line Packages. Then comes a category called ZIP, Zig-zag In-line Package, which basically contains two rows, but the pins are in a zigzag form. That means, if you have two pins continuously here (Refer Slide Time: 07:13), the third pin will be in between these two pins, but in a different row. So, this is known as ZIP package.

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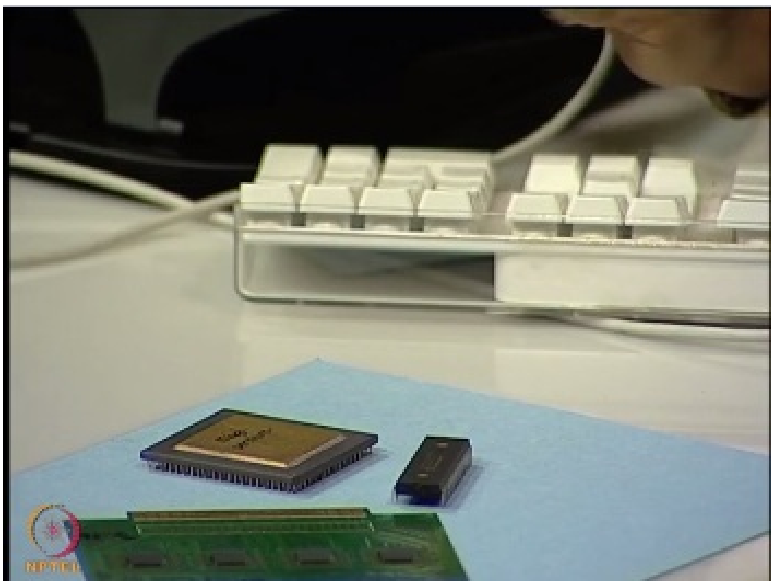

Then, you have Pin Grid Array or Column Package, which I have showed in the last class, the familiar Intel Pentium processor, which has the input output pins in the form of a pin, really thick pins as you can see. Now, you can see the pins. This is a single chip module. All these are single chip modules.

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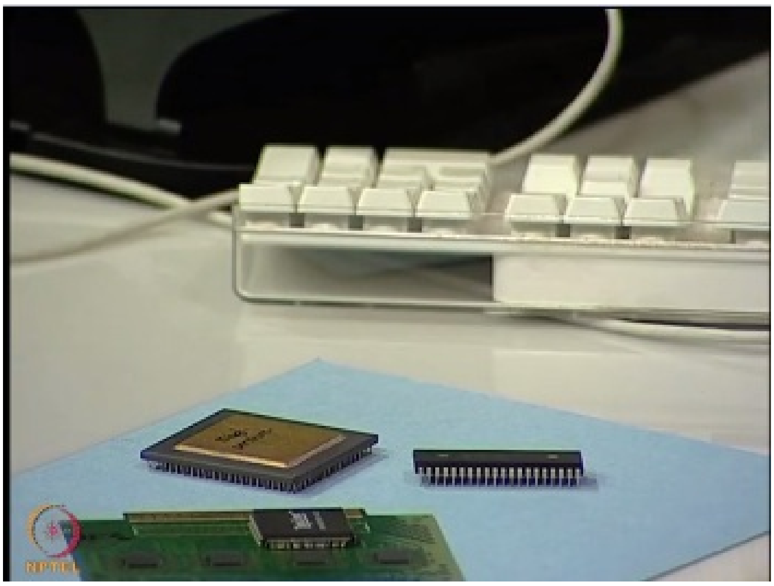

Let us now go to the other category – Surface Mount Package. In the Surface Mount Package, we have what is known as Small Out-line Package. As the name indicates, the Surface Mount Packages will not have or will not have a requirement of the pins going through the printed circuit board. They will be mounted on the surface of the board like this. So, the Surface Mount Packages will not have a requirement for creating holes on the Printed Wiring Board. They will be assembled on the surface of the board as the name indicates. That is why it is called a Surface Mount Technology. If you use Surface Mount Devices, you are working with Surface Mount Technology. So, I will write it here (Refer Slide Time: 08:45) – Surface Mount Devices and Surface Mount Technology.

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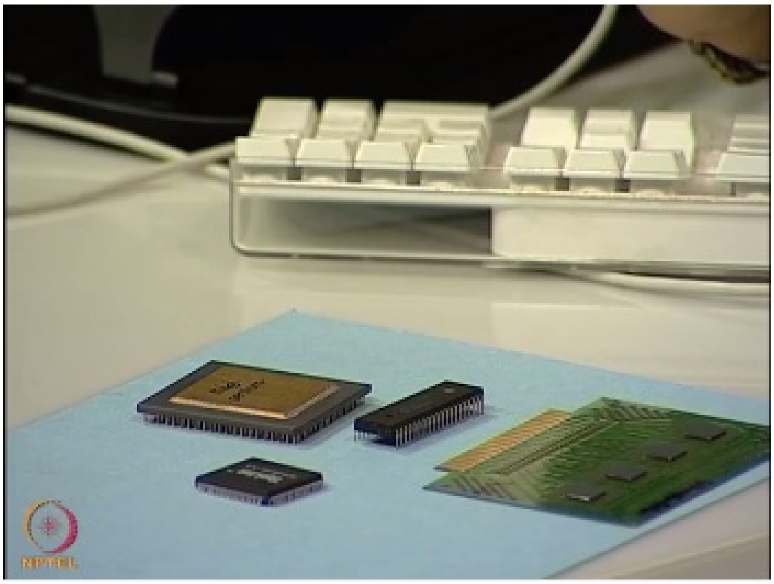

Then, we have the QFP, Quad Flat Pack or Package. What I am seeing here is a Quad Flat Pack because as you see, if I rotate this on all the four sides, you have the pins. The periphery of the package on all the four sides contains the pins. That is why it is called a quad, whereas this is a dual; so, Quad Flat Pack or Package. There are various types of Quad Flat Packages. We will see as we go along.

Then, we have what is known as a Leadless Chip Carrier. If you look at this entire column of components, all of them are mounted on the surface of the substrate or a Printed Wiring Board. So, Leadless Chip Carrier. Then, we have what is known as Plastic Leaded Chip Carrier with Butt Leads. All of these leads as the name indicates, they are very short compared to the Through Hole Packages, where we have lengthy pins. In electrical performance stand point, leads will create a lot of packaging delays. So, the advantage of using Surface Mount Devices is that short pins or short pin distances from the package body will definitely enhance the electrical performance; we are going to see that.

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Then, we have what is known as Ball Grid Array, which is a sort of a work horse for the PCB industry today. Once again, I will show you what is a Ball Grid Array you can see there is a die here, there is a substrate, and if you flip over, you will see the glimmering solder balls. So, the interconnection to the board here is through the solder balls that you see here – that are arranged neatly in a grid. Whereas, in these two cases or in these three cases, the interconnection of the package to the board is through pins. Whereas, in this current state of the art technology, the interconnections is through solder balls. So, if you look at a cross section of such a device, it will be like this (Refer Slide Time: 11:32).

As you can see here in this figure, there will be a series of solder balls, which will establish the interconnection to the board and you can arrange this entire grid in an array format. That is why these are known as area array packages. It utilizes the entire area under the die unlike the Quad Flat Pack or the DIP packages, where only the periphery is used. So, you can now imagine – a BGA package will have very high density in terms of pin density, or you can call it as component density and the number of I/Os can be packed in a smaller area compared to a DIP package or a Quad Flat Pack. So, that is the advantage of using Ball Grid Array.

Then, you have what is known as Tape Automated Bonding. This is also a method of interconnection to the substrate.

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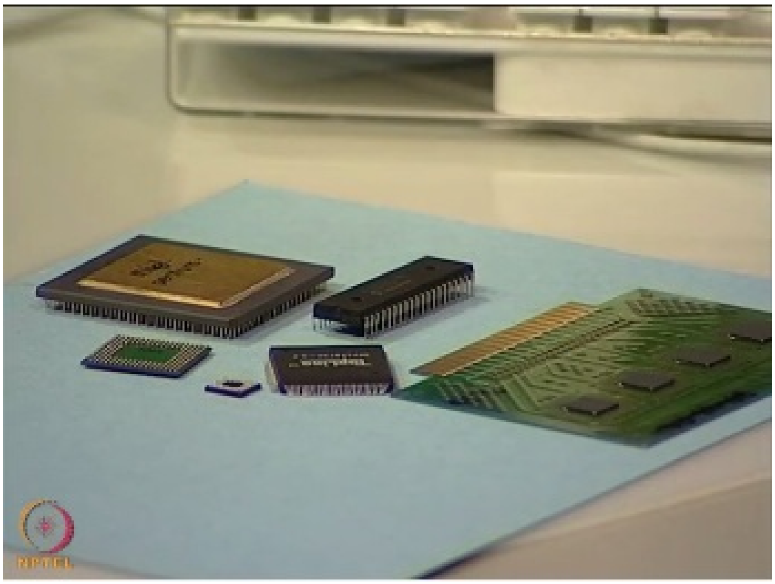

Then, we have what is known as Chip Size Package. For example, I will show you a Chip Size Package here – a very tiny package. It is packaged; it is not a bare die. You can see at the bottom, there is a solder ball, but it is a very small device and the package volume is very less compared to a Ball Grid Array. So, Chip Size or Chip Scale Package; it is also known as Chip Size Package. These are the current technologies. The BGA and the Chip Size Package are very current technologies and we are going to see more of that.

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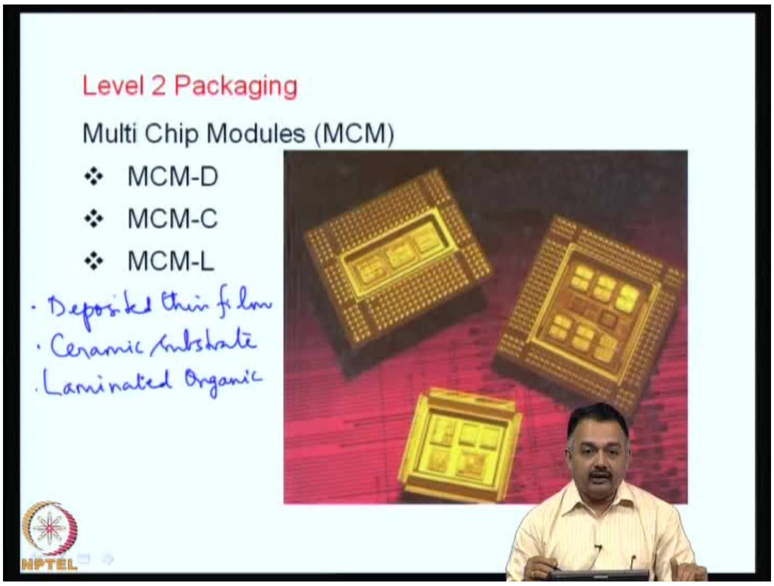

Level 2 Packaging as I mentioned before and by this time, you must be aware that it is an activity where a group of dies here – as you can see, are mounted on one single substrate. You can see in this particular figure, there are one, two, three dies. They are interconnected between themselves on the same substrate and the output is in the form of I/O pins similar to the Intel processors that we see. This is the output in the form of pins. So, in this particular die, you can see more number of devices. Active devices are mounted on the same substrate and they are interconnected. It can be an organic substrate or it can be a ceramic substrate. Then, it has got a provision for ceiling. This particular area that you see will be the provision given for ceiling the dies; totally isolating it from the external environment. Then, you can see the I/O pins. So, this is also one such example.

As you can see here, Multi Chip Modules can be of three types: MCM-D, MCM-C and MCM-L. MCM-D stands for deposited thin film, MCM-C for ceramic substrate, and MCM-L stands for laminated organic material. So, these are the classifications currently available for Multi Chip Modules. Multi Chip Modules are not as common as the Single Chip Modules because it is custom built. Multi Chip Modules are not available of the shelf. For example, I will give you an instance – if you want to create a Multi Chip Module on a ceramic substrate and if you have about 5 dies, you have to procure or decide which of those 5 IC's are. It can be from different manufacturers. Then, you mount them on a same substrate, interconnect them, package them, and then specify to the manufacturers of the Multi Chip Modules, the foundry. Then, tell them what kind of interconnection format you require – whether it should be a pin, whether it should be a lead, or whether it should be solder ball. That is how the process goes. So, you can custom build Multi Chip Modules.

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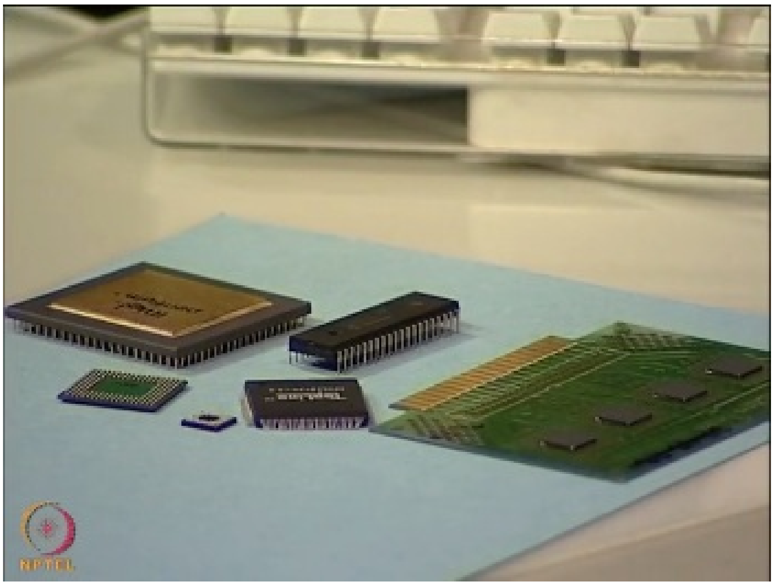

Finally, if you can have a look at it, these Multi Chip Modules will get some kind of a format of this type, but it can be smaller. This can easily go on to a motherboard. So, Multi Chip Modules can also be mounted on to motherboards. I hope it is very clear. Single Chip Modules after they are fabricated, they will be mounted on the motherboard. Multi Chip Modules also will get mounted on to the motherboard and then go through the process technologies as a Single Chip Module.

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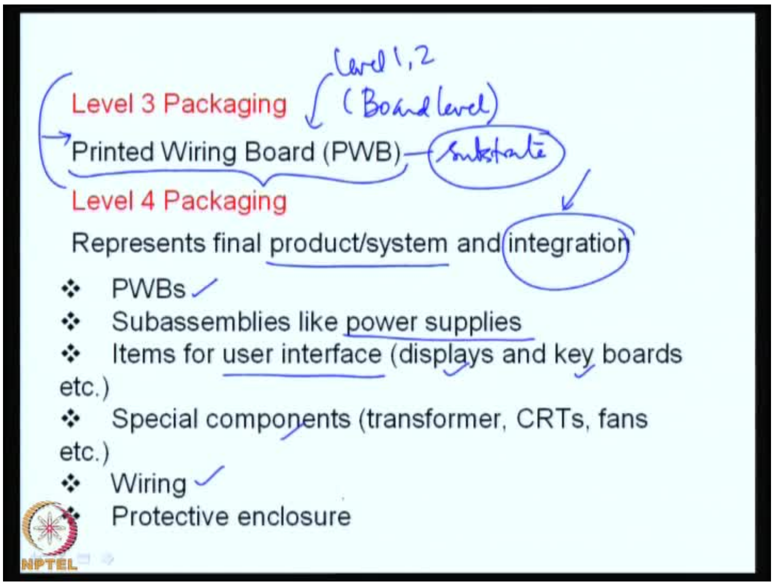

Now, we will see what is Level 3 Packaging. Level 3 Packaging is very simple. It is called board level packaging. It concerns all technologies that go with the manufacturing of the Printed Wiring Board. I would also use the term substrate here because a Printed Wiring Board actually acts as a substrate for mounting various components and interconnecting them on the same substrate. The substrate characteristics are very important in defining the packaging density. The substrate characteristics are very important in defining the electrical performance and thermal performance of your complete system. So, this is a very important aspect of translating your Level 1 Packaging or a Level 2 Packaging into a high density or a high performance level. So, in this course, we are going to spend a lot of time in looking at what Level 3 Packaging is.

As I mentioned before, Level 4 Packaging represents the final product of the system and here it involves a lot of integration – integration of the die, integration of the Printed Wiring Boards in a system. There may be 1, 2, 3, or 4 boards. You have to integrate them and you have to connect them by using connectors. Then, you may have additional electromechanical systems like some transformers and some keyboards. There can be some other devices that will be mounted on the surface of the board, which will interact with your system function board. All of these have to work in unison or harmony. So, in this, you will deal with a lot of PWBs, you will deal with power supplies. Like in a computer, you will see there is a motherboard, there is a graphics card, and then the important thing is your power supply, which is very important to run your system. Then, there will be user interface materials normally in a system like displays keyboards and so on; special components wiring, and then a protective enclosure. Like a desktop or a laptop, or, this system here that you see has got a protective enclosure inside. You have the electronics. That is how it goes – Level 4 Packaging.

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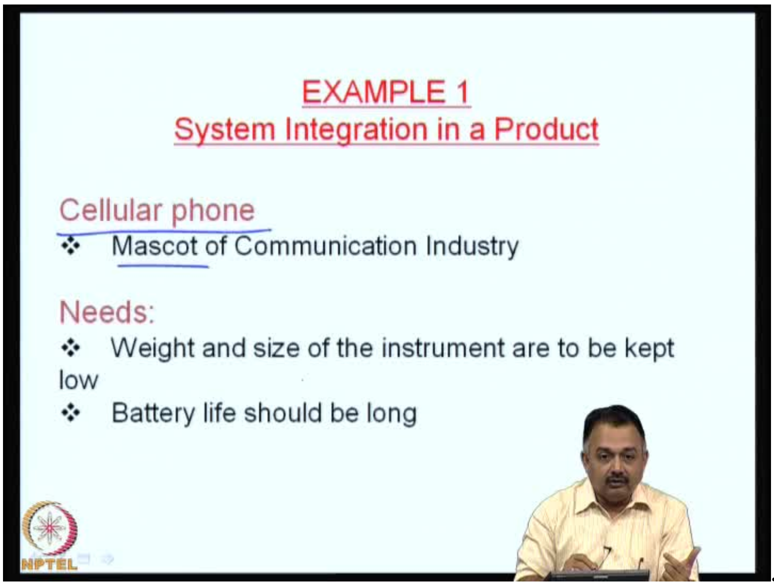

Now I am going to enter into an area where I will give some case studies. The first one is… By the way, these case studies will give you a complete information about how system integration takes place in a product. After going through this case study, I think if you take any product and try to examine it, you can be able to write these kind of points. This is very important for the industry because you are looking at end user concerns. Let us see how it goes.

System Integration in a Product; Example 1: We will take cell phone. Cell phone is our first example. As you know, this is the important activity in communication industry globally today. So, we can say that it is mascot of communication industry. Cell phone defines the growth of this industry because the volumes manufactured in the cell phone industry or the number of mobile phones manufactured is humongously large. What is the need for a cell phone to be manufactured? I mean the manufacturing criteria. Weight and size of the equipment or instruments should be kept low because that is going to be very attractive. Battery life should be long.

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Now, the trend in handheld products globally because you can have manufacturing in India, you can have in Europe, US, and so on. The products are now being manufactured elsewhere and exported elsewhere. So, you should design a system that is attractive both in terms of electrical performance and aesthetics, industrial design, mechanical aspects and so on. The first thing is that the design engineers will be interested in miniaturization. So, lot of thinking has to go into the electrical design aspects of this particular miniaturization concept.

Technology convergence – global technologies are available. Anything that works in India should work in US or in Europe. Application convergence – especially internet; for example, if you are going to use a mobile phone with internet facility, wi-fi, bluetooth. So, there should be convergence of technologies that should be incorporated into your design. Ubiquity – that means a particular application that is used here should be applicable elsewhere when you are travelling. So, that is ubiquity and interconnectivity. Globally affordable cost – as I have repeated number of times, now this is very important, but not at the loss of performance or reliability.

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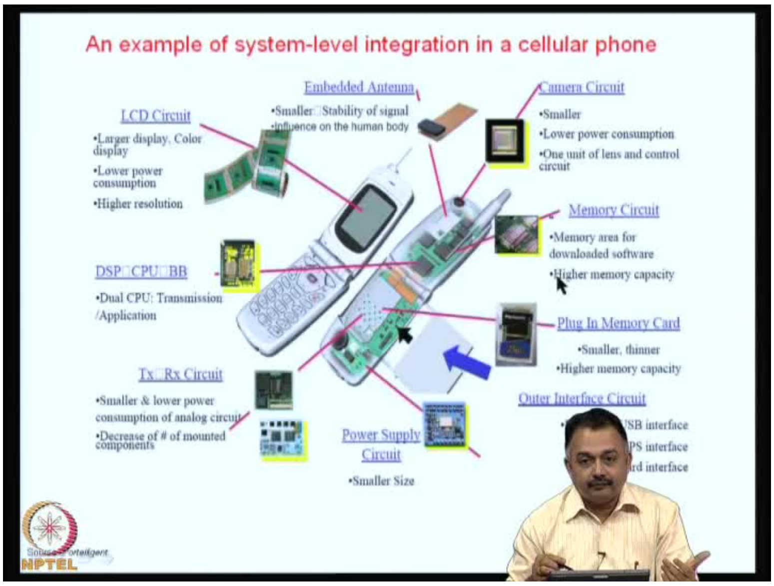

This is a figure where you can see a cell phone or a mobile phone is ripped open and you are able to see the various parts that are present in a mobile phone. Normally, we do not see that. However, when you want to understand the technologies used and when you want to see the electrical design aspects and thermal design aspects that has gone into the manufacturing of this mobile phone, you can see here. So, this is the mechanical casing and you can see the Printed Circuit Boards are placed one over here and the other is kept in this particular part of the device.

Now, I will just list out the various components. You can see there is embedded antennas circuitry on this particular board. So, you have to work on antenna design if you are an electrical engineer. Camera circuit because today, camera becomes very important and the preferred choice. So, it should be smaller, low power consumption and they should have a lens and control circuit. All should be very small. See that the active device that controls this is only this much (Refer Slide Time: 24:06). Then, you have memory circuit. Everybody wants larger space memory area for various applications to download, upload, record and so on. So, memory circuit becomes very important. Then, there is a plug in memory card for the mobile phone, which is stationary inside the mobile phone and that also needs to have a higher memory capacity. Then, you have the outer interface circuit like a bluetooth, USB interface connecting to various other systems, MP3 player and so on. Power supply circuit – again this is going to be very important because the power supply circuit should be small in size. Then, the transceiver or receiver circuit because this is going to also consume power. So, your analog circuitry should take care of low power consumption when you are designing the transceiver receiver circuit.

Here in all of these cases, you must look at how you can reduce the number of mounted components. This is because if the number of components are going to increase in these two substrates (Refer Slide Time: 25:23), then your bulk volume of your mobile phone is going to be huge and the weight will increase. So, that is not a favorable requirement with the consumer.

Then, you have the important things – processor circuits, basic CPU for transmission applications, digital signal processing CPU, and so on will be mounted in one of the boards. You have to look at the latest technologies for using these kind of microprocessors and devices and its associated electrical performance with other devices that is already chosen. Then, you have the display LCD circuit, which is a larger display people want it, should be color, low power consumption, and high resolution. So, electrical designer has to spend a lot of time in doing an electrical design or a circuit design for LCD display and its subsequent connection to the Printed Wiring Board; one of them.

The reliability issues are many here (Refer Slide Time: 26:36) as you can see. If you look at the various components of the mobile phone inside apart from the industrial design or the mechanical package, this could be a plastic package, light weight, of a particular type of material, unbreakable and so on, but inside of it. So, when we say miniaturization or packaging, you are going to spend a lot of time on the electrical design aspects so that your product is really miniaturized. Along with that, you get better electrical performance and a better thermal performance. So, this is a very good example of system level integration in a cell phone.

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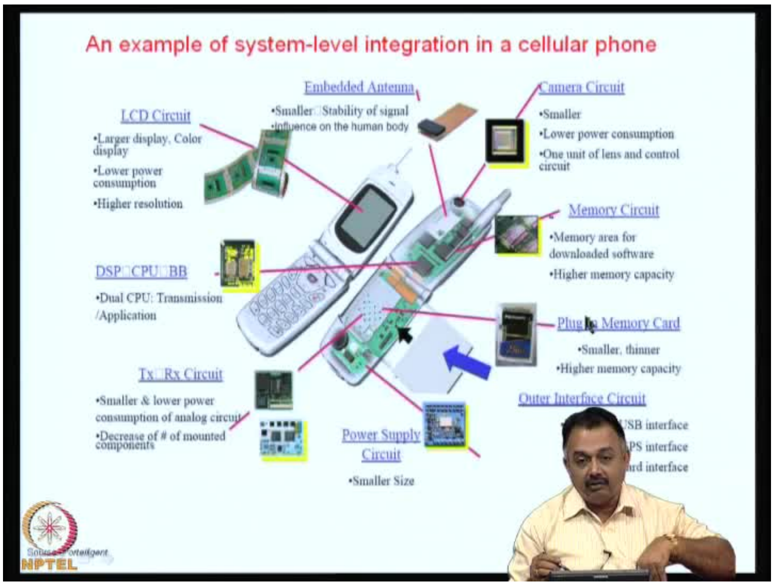

Now, when you use a cell phone or a mobile phone for example, the very common thing is dropping this cell phone. Many of us have dropped the cell phone number of times, but the first thing that we check is – is it working. That means mechanical reliability is also very important because when you drop a device like this one meter from the surface, what happens is – there is a mechanical shock that is exhibited on the surface of the device, which is again propagated into the board, the components, the solder joints, the display and so on. So, there is always a possibility that this mechanical shock can result in failures. So, it is not that erroneous power supply can cause failure or reliability problems, it can also be a mechanical shock, which can get translated into a failure. So, this is also taken care of while designing a mobile phone or a cell phone.

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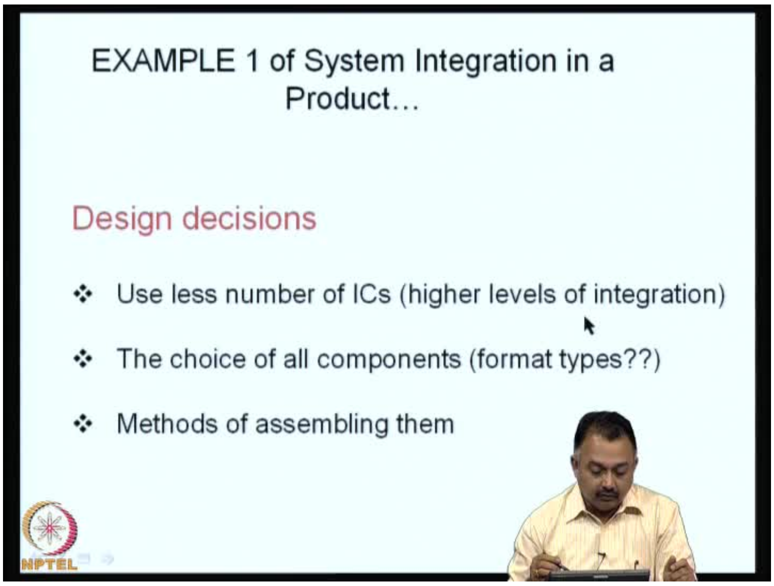

Design decisions in terms of packaging will be: use less number of ICs. Only then, you can go to higher level of integration or you can use ICs, which are already integrated very well. Use packages, which are smaller in size, but higher in performance. You have to decide the choice of all components or format types. This is because if you are going to use different format types as we have shown here – BGA or a DIP or a QFP, then you are going to have problems with assembling these devices. The time taken for assembling these devices of different types is going to be time consuming.

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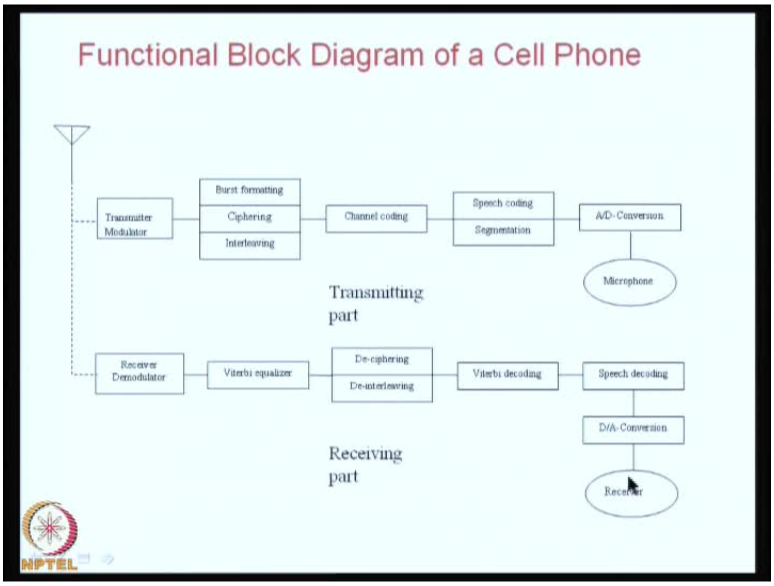

As a designer, you have to spend a lot of time in your circuit design. This is going to take a lot of time. You have to make sure that you have worked with the right specifications that you have initially started with or have been given. So, in a mobile phone, for example, you have a transmitting part and then you have a receiving part and there are sub modules. The block diagram has to be well understood and the choice of components for each of these areas has to be technologically state of the art. While picking the component or selecting the component, you have to look at the format types.

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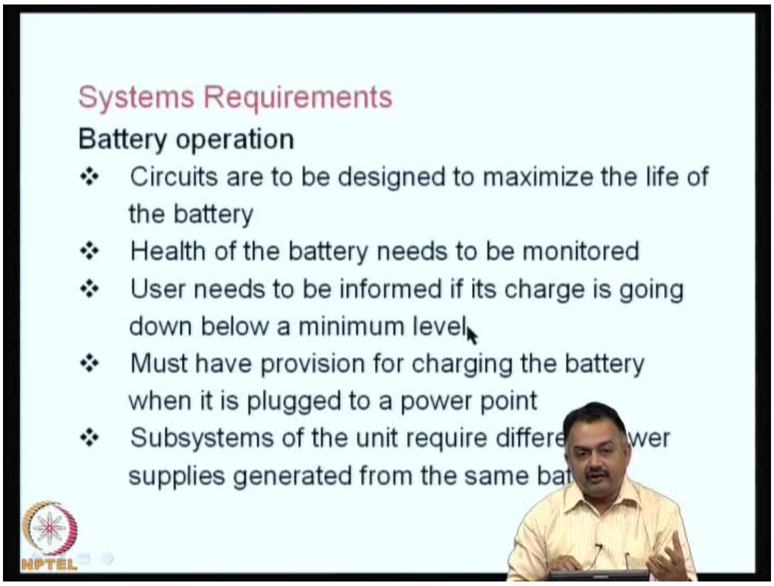

The battery is a very important thing. Circuits have to be designed to maximize the life of the battery. If you are going to design a circuit, which will drain your battery and if it is going to last only for 5 hours or 6 hours, then it is not going to be popular. It is going to be neglected and rejected as a bad packaging electrical design. The health of the battery needs to be monitored. So, if you are going to use a battery and which is a must today, you have to use or look at the battery types available.

There are different batteries. You have to make sure the battery is environmentally friendly, it is slim, it can perform for a larger time, and it is not going to drain the life of the battery because of the poor electrical circuit design. User needs to be informed if its charge is going down a minimum level. So, these are all the user interface information that you have to give for any product today; must have provision for charging the battery when it is plugged to a power point. Subsystems of the unit require different power supplies generated from the same battery. Different devices will require different input voltages so which the battery has to give accordingly. So, those aspects have to be taken care if there are two boards on the mobile phone and your battery is going to supply power. Those aspects have to be taken care of.

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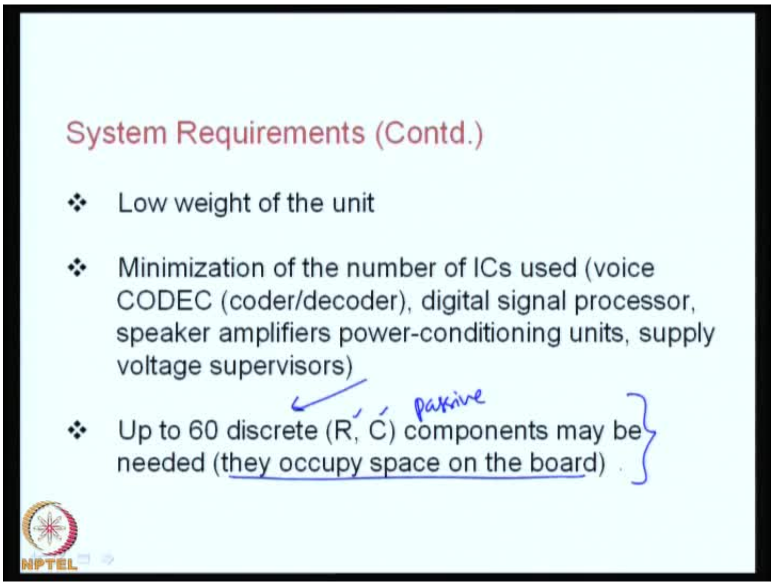

The weight of the unit should be small; minimization of the number of ICs used. There can be a number of ICs like CODEC, DSP, power-conditioning devices, supply voltage supervisors, and so on. More importantly, you are going to use a lot of discrete components. What are discrete components? Passive devices – resistors, capacitors, and so on. They will occupy a lot of space on the board. If you open up any mobile phone and then look at the Printed Wiring board, you will see 50 percent of the space has been occupied by passive devices. If you look at the component density, the passive components are 70 percent of the total number of components on the board. Size wise, volume wise, or area occupied, or you can say – real estate occupied by the passive components on the board is almost 50 percent. So, that is a major design input that you have and you cannot do away with passive components. However, later I am going to talk when we talk about PWB technologies, how to improve the situation by using embedded passives.

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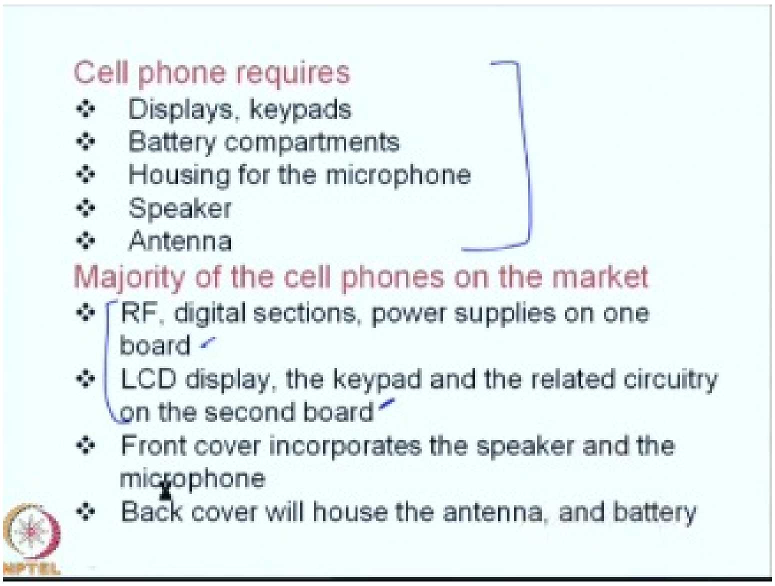

Cell phone also requires displays and keyboards or keypads, battery compartments, the battery profile should be low, housing for the microphone, speaker, antenna, and so on. These are all very common requirements in any mobile phone. The majority of the cell phones in the market have the RF part, digital sections, and power supplies on one board. The LCD display, the keypad, and related circuitry on the second board. So, you can assume that there will be two boards generally. If you are able to pack the entire thing in one board, that is going to be great, but it is still not yet. May be we will be seeing those kind of upgradations or miniaturization very soon. The front cover will incorporate the speaker and the microphone. The back cover will house antenna and the battery. These are all very common observations. Nothing new here, but what I am trying to impress upon you is that these are the things that you have to look at as a design issue.

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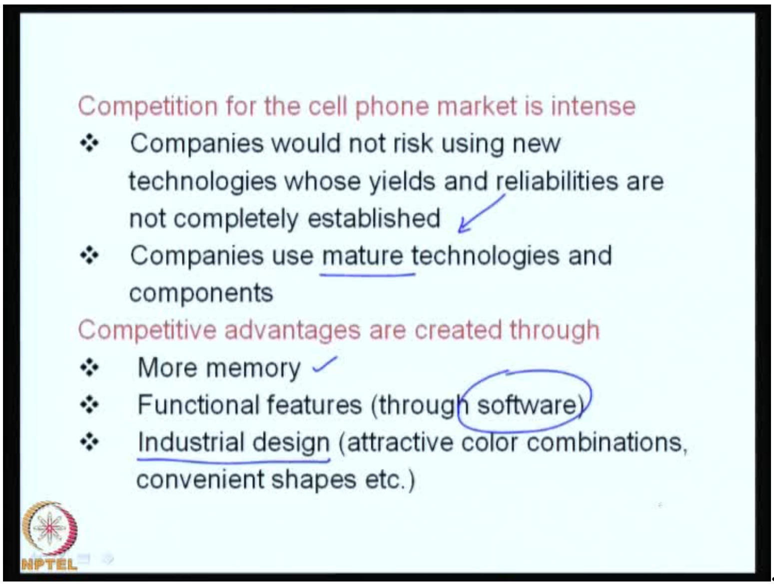

Market or revenue wise competition for the cell phone market is intense. Therefore, when you use a new technology in your product, make sure that you have yield giving models, which means the reliabilities of such a technology should be well established. You do not want to put your money on a technology that is outdated and which will not sell or a new technology, which is not well established. So, you have to be very careful in between in choosing the technologies between outdated technologies and future technologies. There are companies, which take this bold step and become leaders in this market. So, companies use mature technologies, which are at least a year or two old, have been tested for reliability performances.

Advantages are created through more memory; functional features through software. Software is not to be ignored here. Industrial design - this is not a course where we talk about industrial design, but you must appreciate the contribution of ID in the total product development; especially with regards to shapes, sizes, color combinations, the type of material used on the exterior surface, the type of buttons, used and so on.

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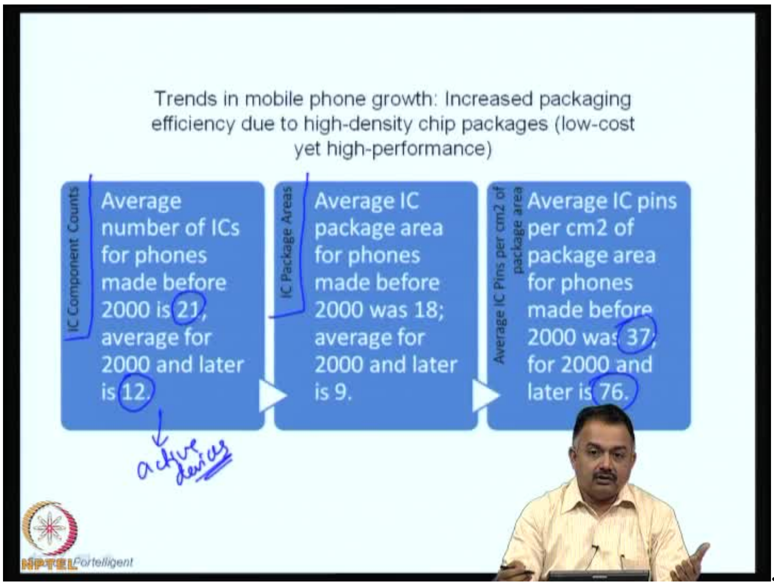

Now I will give you some statistic, which says or talks about the trends in mobile phone growth and which tells you how the packaging efficiency is increasing due to high density devices or ICs packages used. Low cost but at the same time yielding very high performance. If you look at the IC component counts, the average number of ICs for phones made before 2000 is 21; average for 2000 later is 12. So, what does this indicate? This indicates that we were working on some technologies, where the number of ICs were more and obviously, the size of phone was larger. However, today because new packages are available, we are utilizing them and we are able to reduce the number of active devices. So, these are active devices. So, obviously, the component density is very high here.

Now, the next point is IC package areas. Any package, any device will have some package area. So, there is known as a die area and there is a package area. A die is surrounded by package; it can be a plastic package or a ceramic package material. If you look at IC package area for phones made before 2000, it was 18; average for 2000 later is 9. So, here, again you see there is a lot of integration that has taken place. The size of the die might have increased, but the package area has reduced. That means the packaging technologies are using technologies, where you need to put only minimum package on the die to protect it.

The third point that we will see is average IC pins per centimeter square of package area. What does this mean? Average IC pins per centimeter square of package area for phones made before 2000 was 37 and for 2000 and later, it is 72. So, the die size is more, the package area is less, which is exactly what we want. 20 years ago, 30 years ago, these DIP packages that I have shown have package area much more than the die area. If you cut open this device (Refer Slide Time: 38:20) and see, there will be a very small IC and the weight and bulkiness is contributed from the pins and the package material that you see. However, that was a technology 40 years ago. Today, we have new technologies like the BGA and CSP, which if it is used in the mobile phone design, it will result in a very high efficiency. It is called packaging efficiency. If the packaging efficiency needs to be very high, the package area has to be low. So, that is what this means.

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If you look at this, there is no specific reference to any company here. This is a simple example that is sourced from Portelligent. What it basically tries to say is – if you have seen the evolution of mobile phones from 1997 and to 2001, the concept of reducing weight came up in a big way. In those days, we had mobile phones, which was weighing close to 150 grams and today, we are working around less than 100. So, today you can get CDMA phones, which is something like 85 to 90 grams. So, this is the kind of packaging growth that we are witnessing today.

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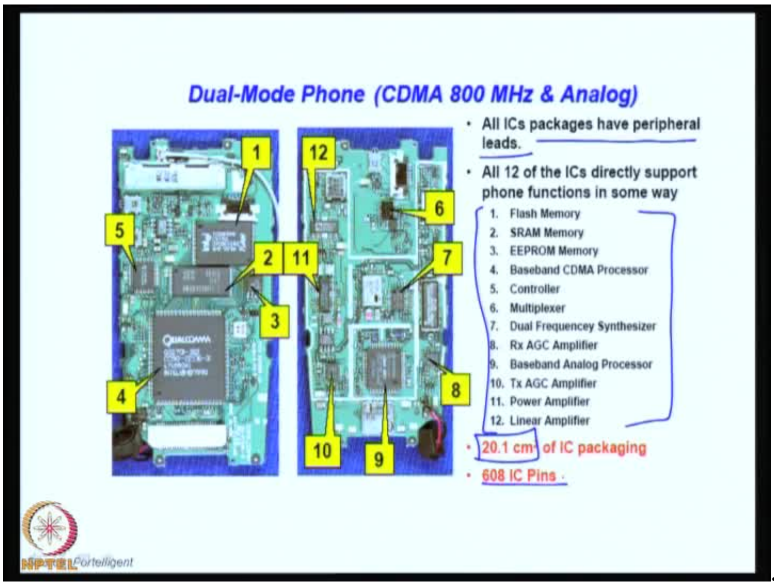

If you look at this picture, which is again a mobile phone opened up so that you can see the two different Printed Wiring Boards or substrate, where all the IC packages are used, mounted along with the passive components. In this particular example, you can see an old technology IC packages have peripheral leads not necessarily area array leads. Each of the 12 ICs in this particular example have got different functionalities: one IC is a Flash Memory, the other is a Controller, the other is Power Amplifier IC, Linear Amplifier IC and so on. So, it occupies a lot of space. The IC packaging by using these 12 ICs is almost close to 20.1 centimeter square and there are 608 IC pins I/Os. This is fairly large.

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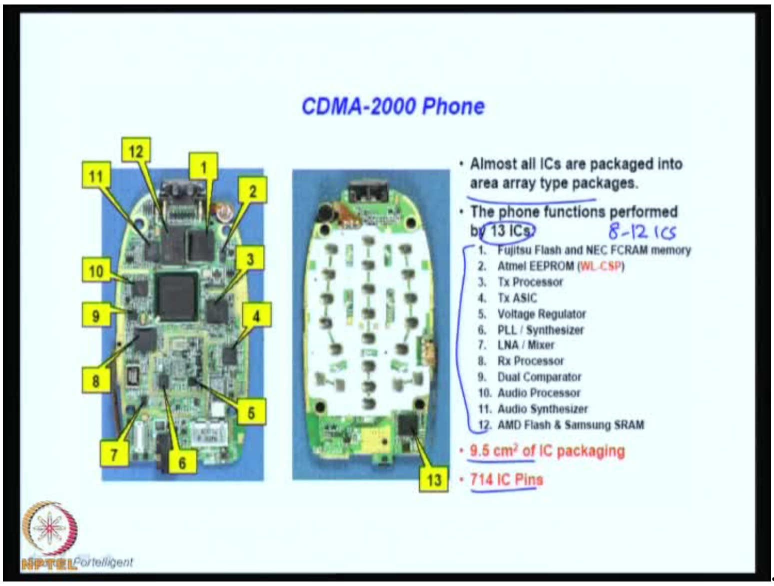

However, if you look at current technology, this is already 10 years old. What I am showing here, but nevertheless you can only expect much better electrical design compared to this here. You can see today's technology uses area array type packages, rather than what we have seen earlier the peripheral array packages. Here, the number of ICs on an average today will be around 8 to 12 ICs. This is the kind of average that we are seeing. In that, most of them are area array packages because the area array technology is well established. However, as an academic activity, in this course, we are going to study right from the peripheral array packages to area array packages and also the bare die devices. In this, again various ICs exhibiting various functionalities, the IC pins are 714 and the IC packaging area is reduced. If you can compare, you can see it is much reduced, but at the same time, the number of IOs are increased, which indicates a good component density growth.

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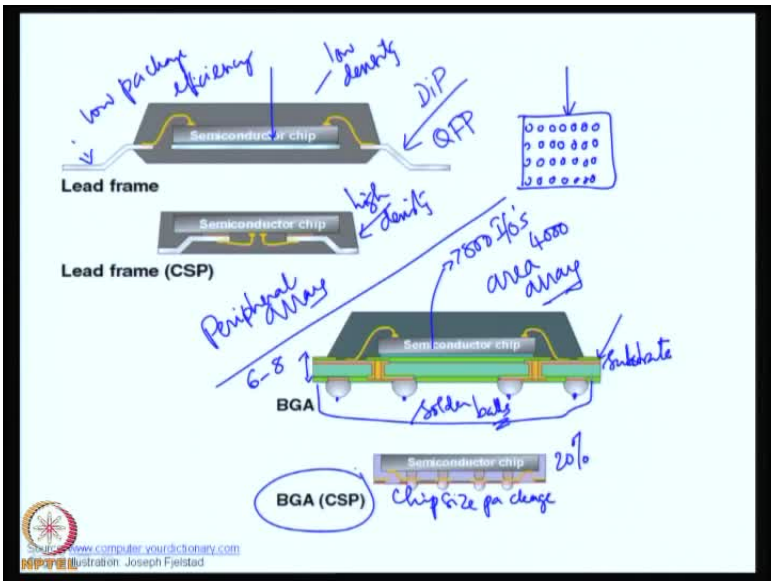

If you look at this figure now, you have seen this package here on this table. The first thing is a lead framed package, which I have showed you – a DIP package / Dual In-line Package or it can also be a Quad Flat Pack. This figure is basically showing you a cross section. So, it can be a Dual In-line Package or a Quad Flat Pack. You can see – there is a semiconductor device here, there is a substrate, and there is a die attached. The green that you see here is a die attach material; an adhesive, which holds the die on to the substrate. Then, you have an interconnection established. This is called wire bond. Interconnection is established between the die pad and the lead frame. This is the lead frame. So, this is of first level interconnection. Once all such interconnections are done for the entire IC, it is packaged with the package material. The black one that you see here is similar to the one that I have shown before – the black DIP package as you can see here (Refer Slide Time: 43:44). So, this gives a very good cross section image of such packages. So, if you rip open a DIP package, you will see these kind of a configuration.

The CSP, which I showed in the last sample, is basically showing. Again, it has got lead frame, but at the same time, you can see the package volume is so low and the die area is almost same as the package area or reverse inversely. The package volume is less. It is almost as the same size as the die area. Whereas, here the die area is small, the package area is very large. So, you can expect that this particular device will have low density or low package efficiency. Whereas, this one (Refer Slide Time: 44:56) will be very high density because you have reduced the package area. More about it in a much later context because now I thought this is the right time to show you some cross sections; otherwise, you will not be able to understand the interiors of any package. So, this is a Peripheral Array Package; what you are seeing at the top, this is the Peripheral Array Package.

Now, you see here, what is shown below is an Area Array Package (Refer Slide Time: 45:34). What is Area Array Package? You have a semiconductor chip at the center, a blue adhesive, and then the green one what you see here is substrate on which the semiconductor chip is mounted. This is a bare die. Now, this one is a substrate on which the chip is mounted. This can be a very high density substrate typically occupying or using 6 to 8 layers of copper for interconnections because you can expect this one to have greater than 800 I/Os. Today, there are area array packages, which are having I/Os as much as 4000. So, here the interconnections are established by these solder balls instead of the lead frame pin here. We are now going to use solder ball technology for establishing connections with the board. So, this will utilize the entire area under the die. We must imagine this to be a continuous matrix. So, if I can draw a picture of the bottom side of this chip, you will have a lot of solder balls. Because you are using this technology, you are utilizing more area under the die, the number of I/Os will increase, and therefore, the package density is very high.

Similarly, this one except that the package area is much less compared to the BGA, this is known as Chip Size Package (Refer Slide Time: 47:31). As the name indicates, the package area and the chip area are almost the same, just about a 20 percent difference. By definition, the package area should not exceed 20 percent of the die area. If it does not exceed, then it classifies as a CSP. I hope it is clear.

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Similarly, we will now look at GSM phones, where again, over the years, we have seen for example, this particular model from 250 grams. Can you imagine the weight of this particular product coming to almost 85 grams? Today's standard is around 85 to 100 grams. People do not buy a product, if it is going to exceed 100 grams. So, that is the kind of impact packaging – both mechanical packaging and electronic systems packaging have on the market.

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This is again new technologies used in current day cell phones, where people are using BGA packages to enhance the electrical performance; they are using stacked processors. That means one processor is stacked over the other by suitable technologies. So, 3-D packages are being used and Multi Chip Modules with low profile / low thickness is also being used. So, these are some of the examples that I can give, which shows change in manufacturing using new technologies at the packages level.

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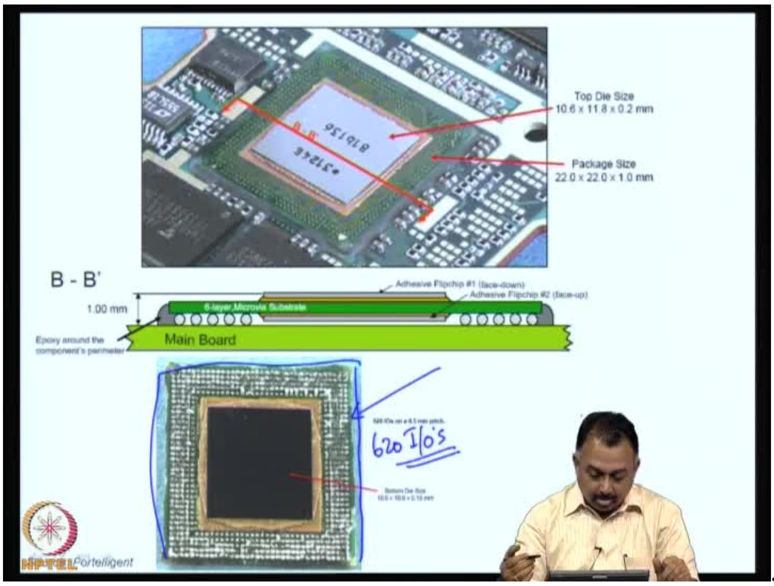

This is an example of the solder ball array. As you can see series of solder balls here, it is occupying the entire area under the die. This is the die and you can see how many? There are 620 I/Os on this particular example, which is very large. So, there are FPGA modules today, which come with 1200 I/Os, 1200 pins, which you have to handle efficiently without even a single error during assembly.

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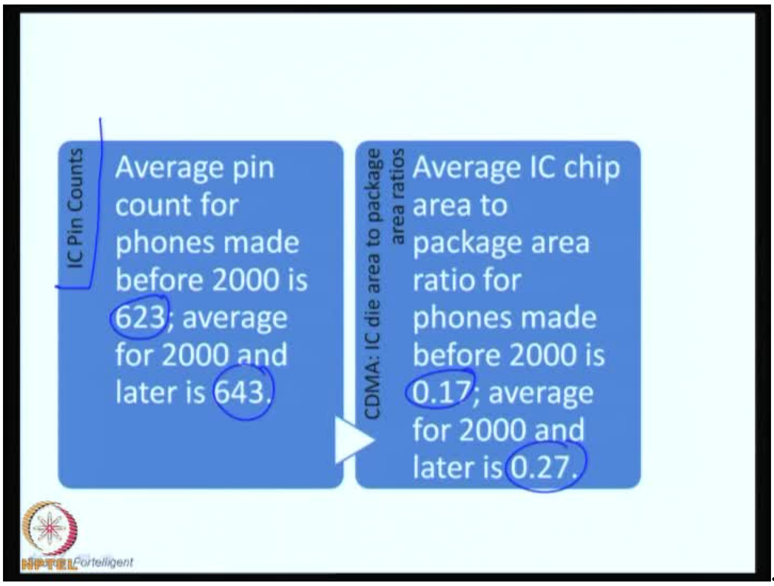

Another statistic, which I would like to give, is - IC pin counts for GSM phones. Average pin count for phones made before 2000 is 623 and average after is 643. If you look at die area to package area, which I think I described for the CDMA also, you can see – here it is 0.17, 0.27. So, the efficiency has to increase.

The first example – we have covered most of the aspects that an engineer should think about in terms of evolving or bringing out a new mobile phone in the market. As you can see, it is not very simple. It is very complex because you have to look at electrical issues, thermal issues, economic issues, industrial design issues to make the product comfortable in a consumer's hand; other aspects like aesthetics, and so on.

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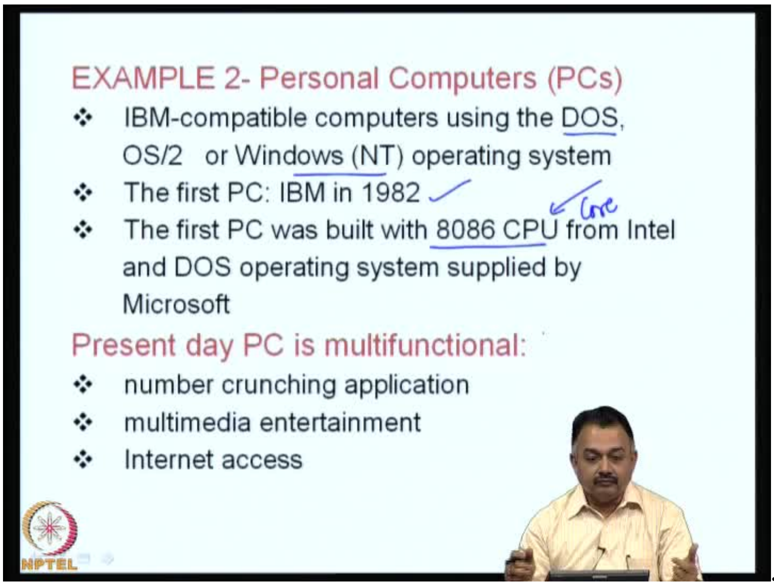

The second one will be Personal Computers. This is the second case study that I am trying to give you. If you look at Personal Computers, there are many in the market today. I am just trying to look at a very simple example. This need not be the perfect example for analyzing a Personal Computer and its packaging problems, but let us take a simple case study. IBM-compatible computers using DOS was once there. Now, we have Windows. Earlier it was NT, but now we have various other Windows operating systems. These are all brief history: In 1982, first P C and then we had various processors 8086. I also showed you how Intel microprocessors have used currently 45 nanometer technology to bring about core processors with very high performance, large die size, but at the same time, millions of transistors being packed into the die.

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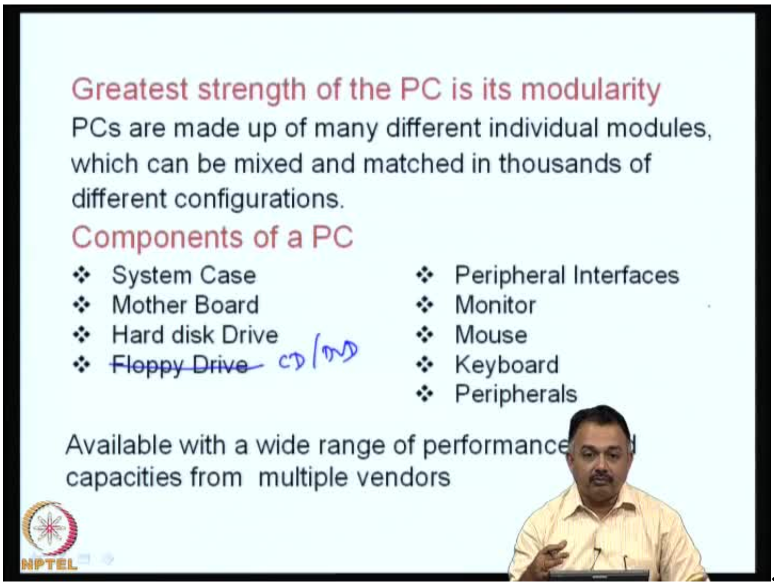

Present day PC is multifunctional. We require lot of activities, lot of calculations, internet access, and various other interfaces are being used. Generally, if you want to make a desktop PC, you will have different modules, which can be mixed and matched with different configurations components of a PC. Typically, you have a system case, a motherboard, hard disk drive, there was once the floppy drive. However, today we are talking about CD drives, DVD drives, then peripheral interfaces, monitor, mouse, keyboard, peripherals, and so on. So, there is a wide variety of choices. Depending upon what core processor you want to use and what kind of graphics utility you want to use, you can build your own PC or you can order custom build a particular PC.

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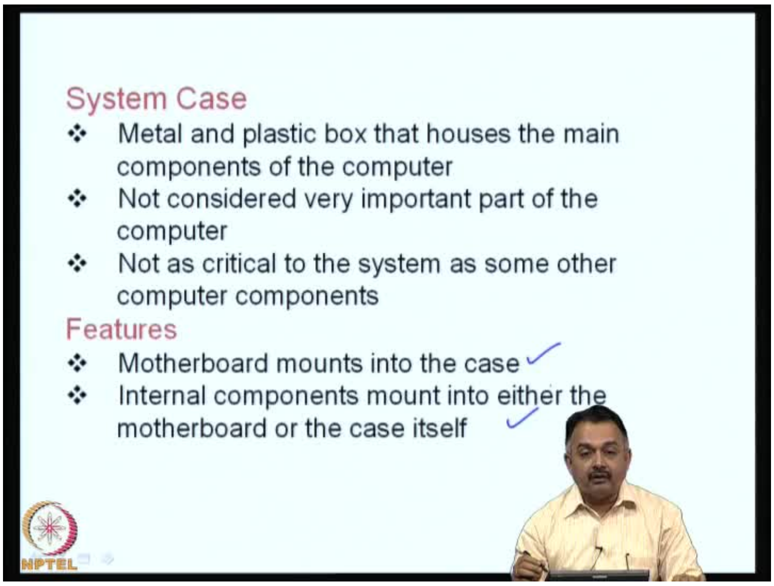

System Case - again metal or plastic box; earlier it was metal, and then came the plastic. Then, again people have improved on these materials so that there is minimum electromagnetic interference from the body of the computer, which will not reduce the electrical performance, but it is not a typical packaging activity. Not critical to the system as other active devices that are mounted core to the processor. There is a motherboard that goes into the case. Internal components are built around the active device.

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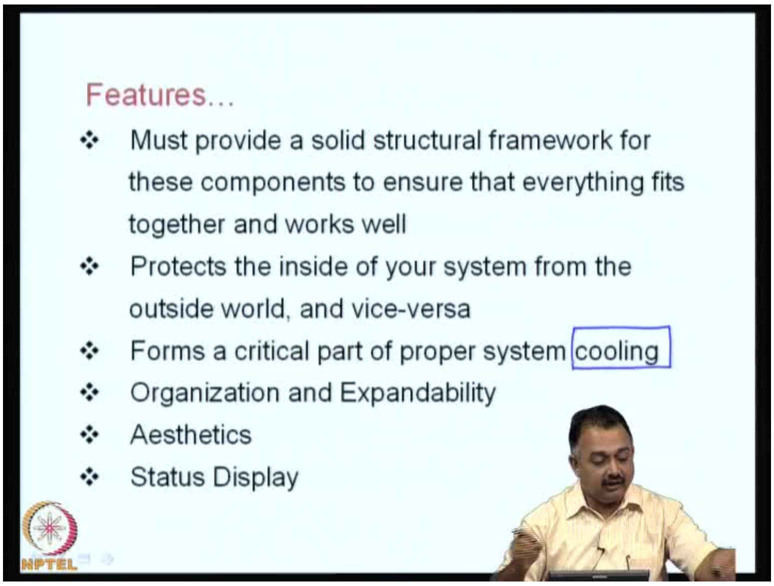

There should be a solid structural framework so that everything works well in harmony with the active device. It protects your system from the outside world and also vice-versa. There should be a definite cooling mechanism for every PC. So, are you going to use a heat sink? For example, this is an example of a heat sink (Refer Slide Time: 54:34). A small heat sink – this is made out of aluminum; this can be mounted on a processor to remove heat. You can see the configuration of a heat sink is – you can see the corrugated structures. That means, you are providing more surface area to remove the heat away from the device. Then, aesthetics, status display, and so on.

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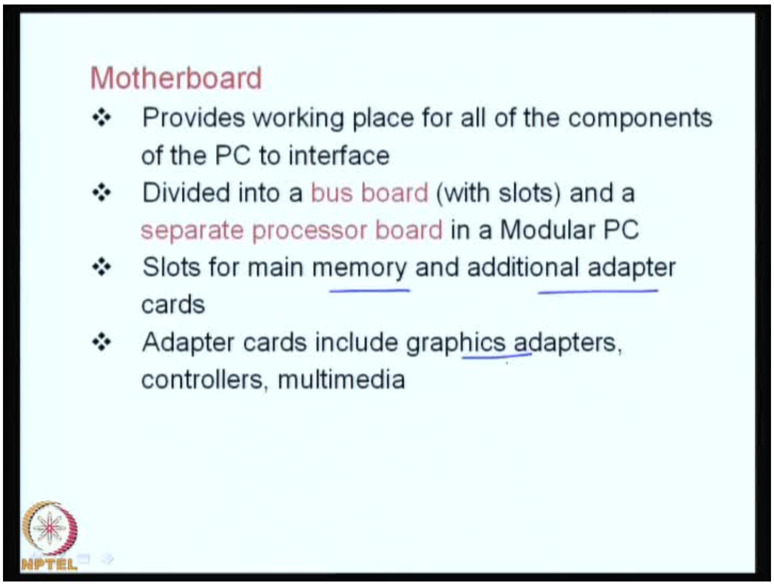

Motherboard - lot of time will have to be spent by the electrical designer in designing the motherboard and its interface. Then, there will be additional memory cards, adapter cards, and so on; graphic adapters, multimedia systems or kits, and so on.

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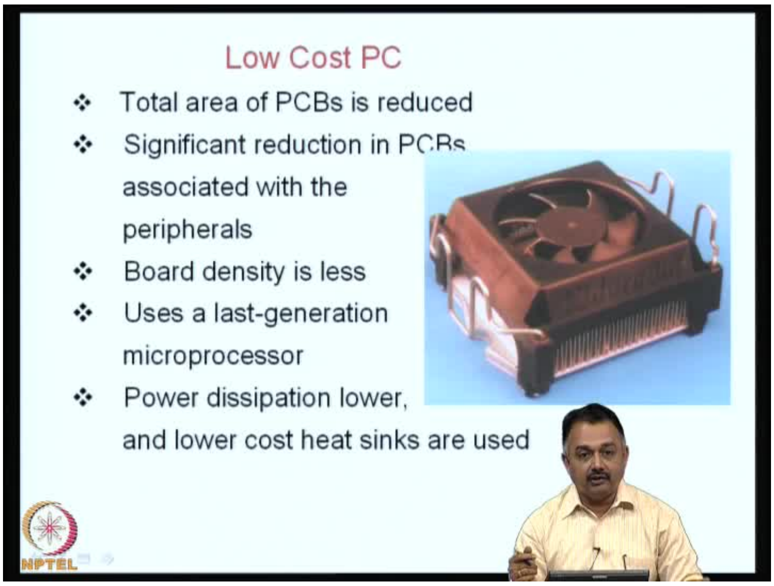

This is a desktop PC; but if you want to build a low cost PC, then you can compromise or you are forced to compromise on the selection of the components, which can be very expensive. In that case, the number of PCBs / PCB area has to be reduced. There should be significant reduction in PCBs associated with the peripherals. Board density will be less. You will also always use a last-generation microprocessor compared to a current processor because you cannot afford the cost to sell a low cost PC. Power dissipation again will be lower and low cost heat sinks will be used. So, when you say low cost, everything is getting directly reflected on the choice of materials, the choice of active devices, the substrate material, the thickness of the substrate, and so on. So, in the context of PCs, if you want a high performance PC, then you have a different set of packaging considerations; if you want a low cost PC, then you have to completely switch into various other categories of selection of materials and design.

We will stop here today, where I have given two examples: one is the mobile phone as a case study and the second is the Personal Computers. In the next class, we will take up another case study starting with automobiles and then proceed with concluding this chapter 1, which is the Overview.

Thank you.